USING FAIRCHILD INTEGRATED CIRCUITS AS MONOSTABLE MULTIVIBRATORS*

By Robert D. Ricks

I. INTRODUCTION

The one-shot, or delay, multivibrator circuit is well known and extensively used throughout the electronics industry. This paper deals with the use of Fairchild Micrologic® in this type of circuit and presents in graphic and tabular form the results of extensive tests of the electrical distribution and temperature-coefficient characteristics of μL® in multivibrator configurations. These data will enable the circuit designer to make accurate predictions of pulse width and temperature-coefficient characteristics for μL in the various circuit configurations. Complete instructions for using μL elements in multivibrator circuits are given, including methods of calculating temperature compensation.

To clarify the particular factors involved in designing multivibrators with μL we will discuss first the problems encountered in circuits constructed with discrete components. In a discrete-component multivibrator circuit (see Fig. 1) two factors can affect pulse width: (1) using different Q_1's and Q_2's, and (2) circuit temperature coefficient.

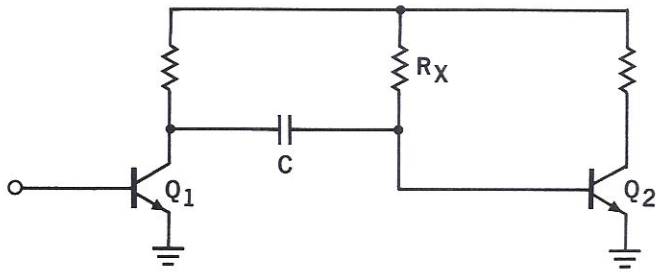

Fig. 1. Multivibrator circuit constructed with discrete components.

Variations in V_{CE}(sat) of Q_1 from unit to unit will affect the output pulse width in the following manner: Ideally, when a positive-going input pulse is applied to the base of Q_1, the timing capacitor will be driven negative with a voltage waveform equal in amplitude to the power-supply voltage minus the V_{CE}(sat) of Q_1. Assuming constant power-supply voltage, any change in V_{CE}(sat) of Q_1 will change the amplitude of the voltage waveform driving the timing capacitor and therefore the output pulse width, since the recharge time back to the turn-on threshold of Q_2 will depend on how far negative the timing capacitor was driven.

Variations in V_{BE} of Q_2 from unit to unit, which may amount to several hundred millivolts, affect output pulse width by changing the point on the timing capacitor recharge curve at which Q_2 is again saturated.

Changes in ambient temperature also affect the output pulse width by causing variations in the threshold or firing point of the base-to-emitter diode of Q_2 and therefore variations in capacitor recharge time.

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These effects of variations in unit parameters and ambient temperature can be reduced considerably if the power-supply voltage is at least ten times greater than the V_{BE} of the devices used (i.e., typically >6 V for silicon and >3 V for germanium).

Now let us consider the multivibrator circuit constructed with μL elements, an example of which is shown in Fig. 2. The effects of variations in unit parameters and ambient temperature described above also apply here, but the method of decreasing percentage change in V_{BE} and V_{CE}(sat) by increasing power-supply voltage is not applicable because μL elements are specified for operation at 3.0 or 3.6 volts, depending on the type of unit used. *

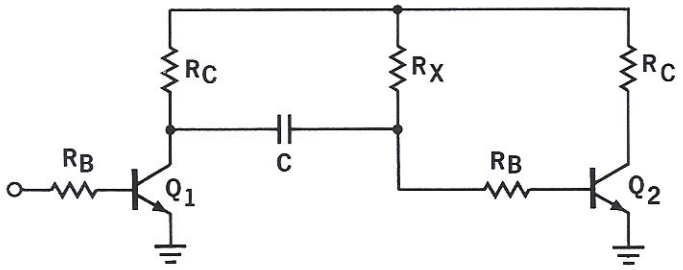

Fig. 2. Multivibrator circuit constructed with μL elements.

An additional factor which affects pulse width and temperature stability in the μL multivibrator circuit is the integrated current-balancing resistor R_B shown in Fig. 2. This resistor may vary as much as 25% from its design center value. Since the nominal input impedance of the integrated transistor is on the order of 50 Ω this tolerance has an appreciable effect on the threshold voltage of Q_2 and therefore on the overall output pulse width as outlined above. In addition, an integrated resistor exhibits a positive temperature coefficient of approximately 0.15%/°C over almost the full military temperature range of -55°C to +125°C, and this additional temperature coefficient must be taken into consideration when attempting temperature stability calculations.

II. TEST RESULTS

Extensive measurements were taken of the characteristics of μL circuits in the two different monostable multivibrator configurations shown in Figs. 3a and 4a with the μL elements indicated in block form. The circuit of Fig. 3a was used with (1) half a μL 914 driving half a μL 914, and (2) half a MWμL 910 driving half a MWμL 910. (For schematic diagrams of individual elements see Figs. 3b and 3c.) The circuit of Fig. 4a was used with (1) half a μL 914 driving a μL 900, and (2) half a MWμL 910 driving a MWμL 909. (For schematic diagrams of the 900 and 909 buffer elements see Figs. 4b and 4c.)

The circuit of Fig. 4a has a much higher drive capability than that of Fig. 3a because a buffer element forms the output stage, but the Fig. 3a circuit has the lowest can count. As will be discussed below under Circuit Performance Temperature Coefficient vs R_X, the $\frac{910}{2} \longrightarrow$ 909 combination lends itself most readily to temperature stabilization. However, the other combinations can be used over the full temperature range by following the temperature compensation methods discussed in the addendum.

Tests were made on ten units of each of the elements under investigation, selected at random from a production bin of full-temperature-range devices,† and the results of the tests are given in the graphs of Figs. 5 through 16, which are discussed briefly below. A study of these graphs reveals that circuit performance and output pulse width are functions of the value of the external resistor R_X (shown in Figs. 3a and 4a).

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*i.e., full-temperature-range units (-55°C to +125°C), mid-range units (0°C to +100°C), and industrial units (+15°C to +55°C).

†No attempt was made to "worst-case" the parameter spread within the full-range family; therefore the limits given in the figures and charts are not guaranteed but are rather the limits that will be found in the majority of cases. If either mid-range or industrial elements are used in place of full-range devices, the limits on the charts and graphs may increase by 10% for mid-range devices and 30% for industrial.

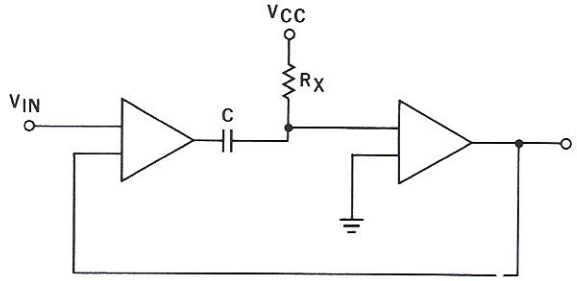

Fig. 3a. Multivibrator configuration for $\frac{914}{2} \rightarrow \frac{914}{2}$ or $\frac{910}{2} \rightarrow \frac{910}{2}$.

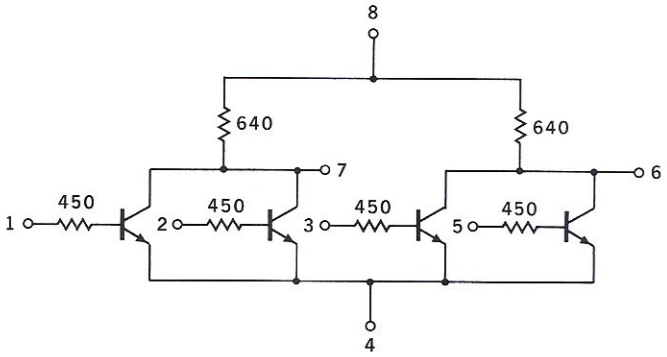

Fig. 3b. Schematic diagram of μL 914.

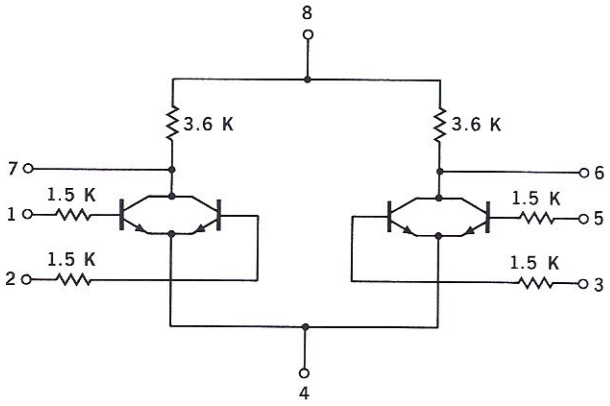

Fig. 3c. Schematic diagram of MWμL 910.

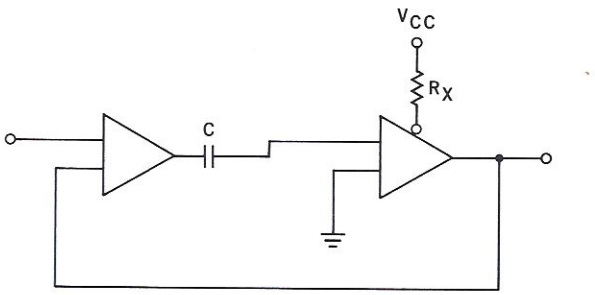

Fig. 4a. Multivibrator configuration for $\frac{914}{2} \rightarrow 900$ or $\frac{910}{2} \rightarrow 909$.

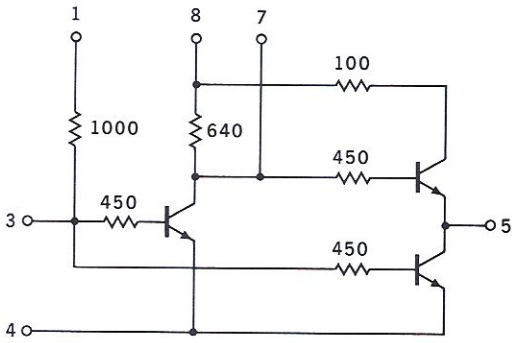

Fig. 4b. Schematic diagram of μL 900.

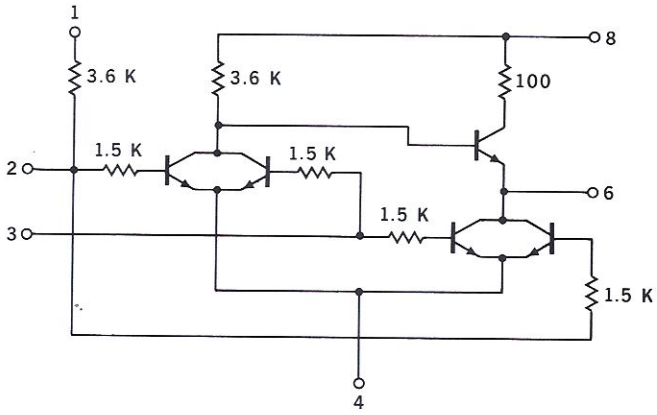

Fig. 4c. Schematic diagram of MWμL 909.

Table I gives the β-limited values of R_X for each of the four configurations over the -55 to +125°C temperature range. Any increase in R_X above these limits will disable the circuit.

TABLE I

Limit Values of External Resistor R_X (Ohms) Versus Temperature (°C) for Various μL Combinations

Temperature	$\frac{914}{2} \rightarrow \frac{914}{2}$	$\frac{910}{2} \rightarrow \frac{910}{2}$	$\frac{914}{2} \rightarrow 900$	$\frac{910}{2} \rightarrow 909$
-55	5 K	10 K	5 K	20 K
-25	10 K	10 K	5 K	30 K
0	10 K	10 K	8 K	30 K
+25	10 K	10 K	10 K	30 K
+50	10 K	10 K	10 K	50 K
+75	10 K	10 K	10 K	50 K
+100	10 K	20 K	10 K	50 K
+125	10 K	20 K	10 K	50 K

Circuit-performance temperature coefficient versus R_X (Figs. 5-8)

Graphs of the circuit-performance temperature coefficient versus R_X for each of the configurations are given in Figs. 5 through 8. It will be noted that the $\frac{910}{2} \longrightarrow 909$ combination (Fig. 8) is the only configuration whose temperature coefficient starts from a positive value at zero R_X. As R_X is increased, the average temperature coefficient approaches zero. This phenomenon can be explained as follows: When the integrated resistor (R_B) exceeds approximately 2 K the normally negative circuit temperature coefficient goes positive. As will be noted from the schematics, the MWμL 909 buffer element is the only one of the four elements in question with an integrated resistor larger than 2 K in value to which R_X can be attached. Therefore, as R_X is increased the overall temperature coefficient of the series pair of resistors (i.e., R_X with temperature coefficient of zero and integrated resistor with temperature coefficient of 0.15%/°C) becomes less. With a value of R_X equal to approximately 4 K the average temperature coefficient for this circuit is zero. (If pulse widths other than those available with R_X = 4 K are required, stable operation over the temperature range can be achieved by connecting either buffer element as a standard multivibrator, without using the internal timing resistor, and using the compensation methods outlined in the addendum.)

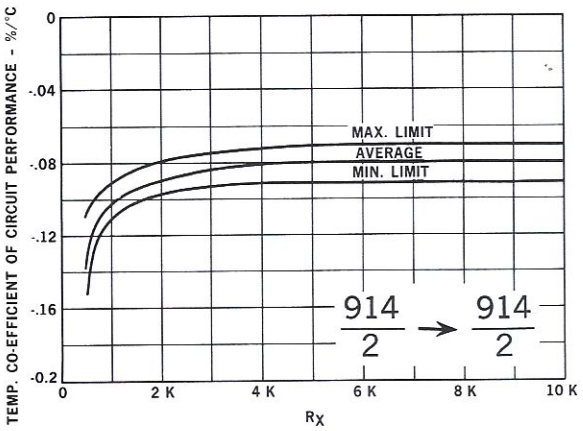

Fig. 5. Temperature coefficient of circuit performance vs. external resistance (Rx)

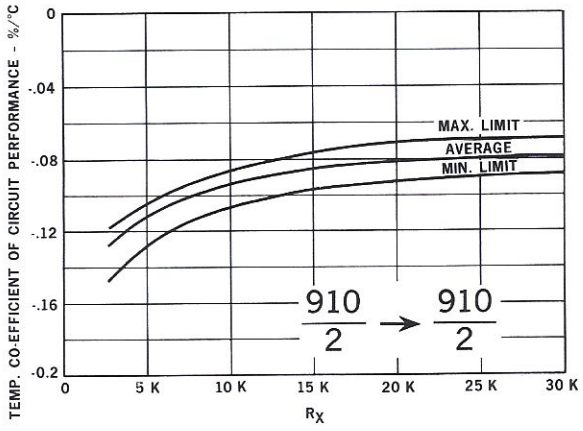

Fig. 6. Temperature coefficient of circuit performance vs. external resistance (Rx)

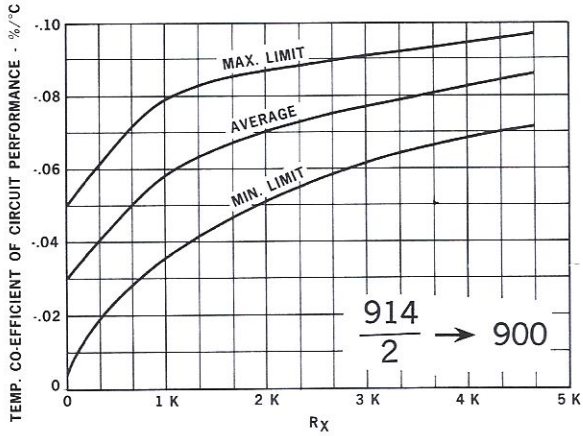

Fig. 7. Temperature coefficient of circuit performance vs. external resistance (Rx)

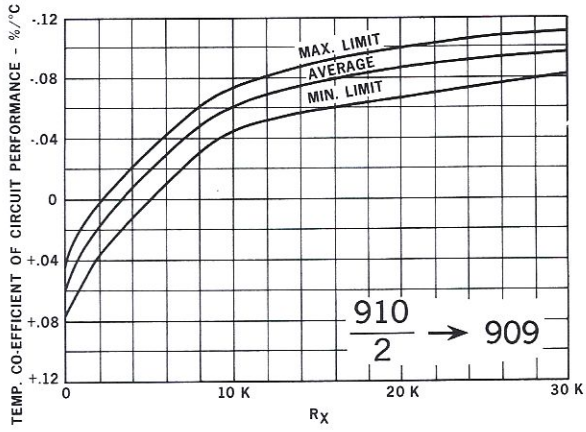

Fig. 8. Temperature coefficient of circuit performance vs. external resistance (Rx)

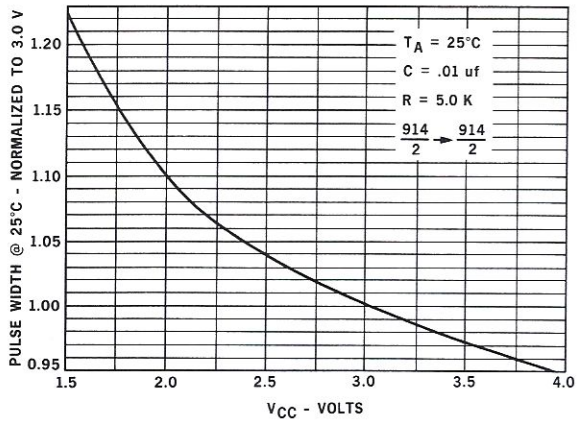

Fig. 9. Normalized pulse width vs. V_{cc} for $\frac{914}{2} \rightarrow \frac{914}{2}$.

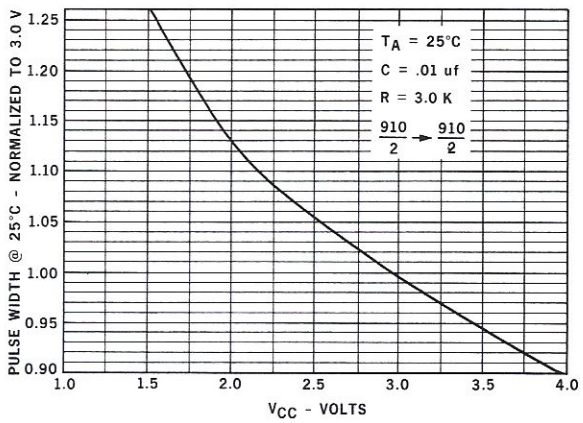

Fig. 10. Normalized pulse width vs. V_{cc} for $\frac{910}{2} \rightarrow \frac{910}{2}$.

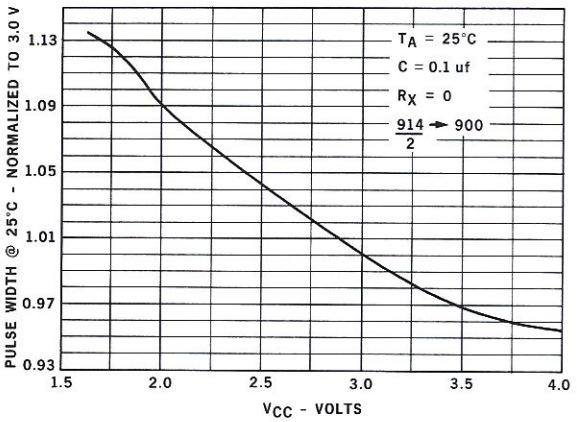

Fig. 11. Normalized pulse width vs. V_{cc} for $\frac{914}{2} \rightarrow 900$.

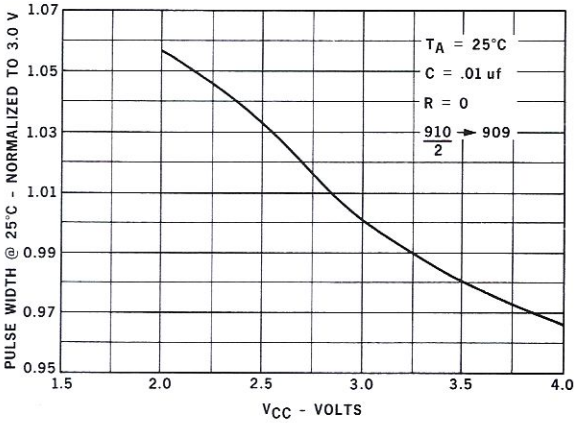

Fig. 12. Normalized pulse width vs. V_{cc} for $\frac{910}{2} \rightarrow 909$.

V_{CC} versus output pulse width (Figs. 9-12)

Figures 9 through 12 show the effect of changing supply voltage on output pulse width for each of the configurations. Pulse widths shown are normalized to the values at 3 volts V_{CC}. All four charts were taken from data tabulated from only one set of R-C timing elements. Increased stability with changes in V_{CC} can be realized by further increasing the magnitude of the timing resistance, thus more nearly providing the action of a constant current source.

Pulse width versus R_X for constant capacitance (Figs. 13-16)

Figures 13 through 16 are timing charts giving the resistance (R_X) and capacitance values necessary for any output pulse width. As a general rule, for any given pulse width the ratio of resistance to capacitance should be as high as possible since the physical size of a resistor, unlike that of a capacitor, does not change with its value. Furthermore, the larger the value of R_X the less will be the effect of the integrated resistors with their loose tolerances and hence the tighter the reproducibility of pulse width.

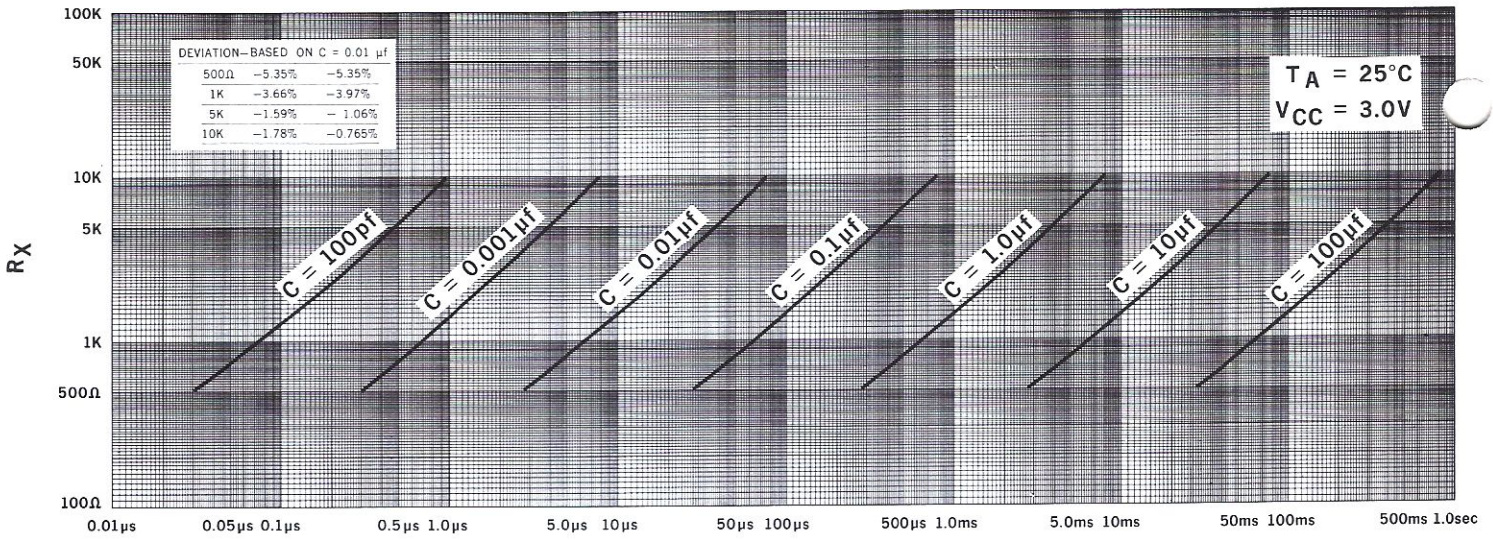

FIG. 13 PULSE WIDTH VERSUS EXTERNAL RESISTANCE (CONSTANT C) FOR $\frac{914}{2} \rightarrow \frac{914}{2}$

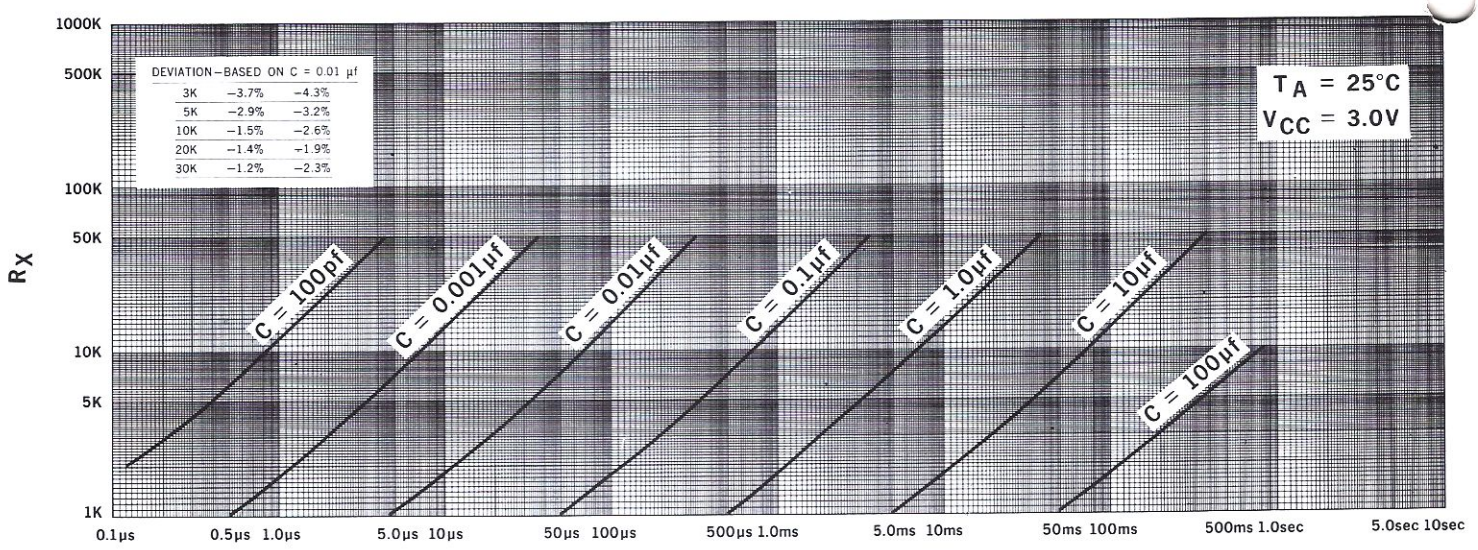

FIG. 14 PULSE WIDTH VERSUS EXTERNAL RESISTANCE (CONSTANT C) FOR $\frac{910}{2} \rightarrow \frac{910}{2}$

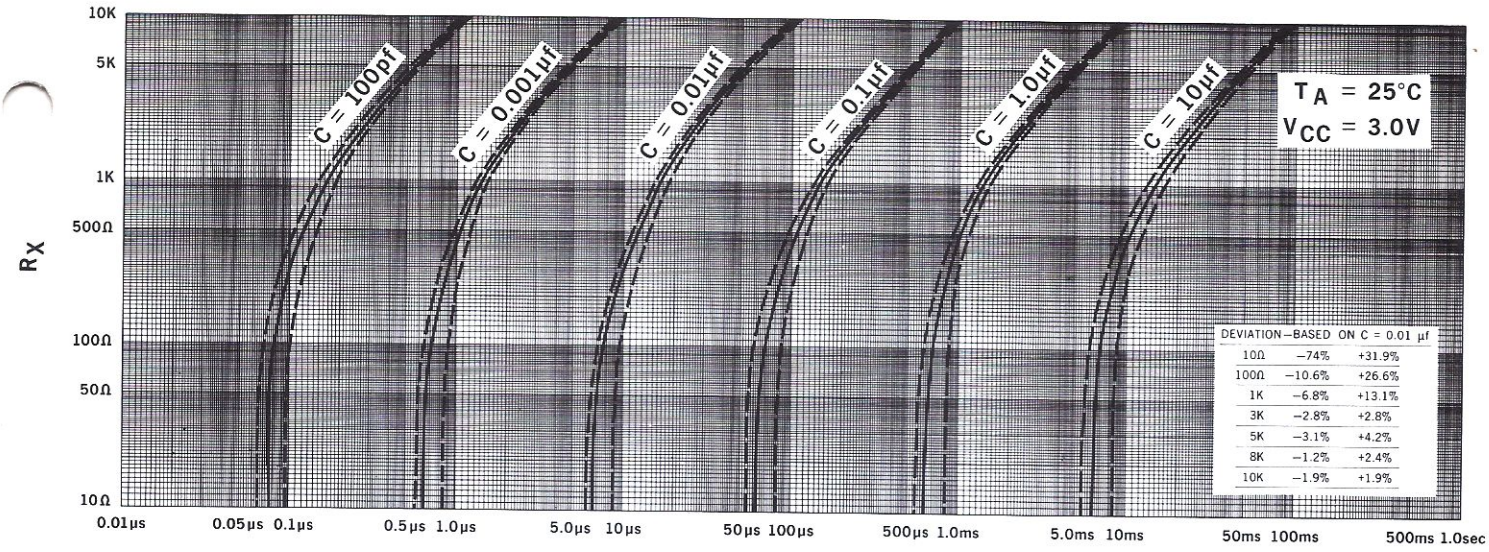

FIG. 15 PULSE WIDTH VERSUS EXTERNAL RESISTANCE (CONSTANT C) FOR $\frac{914}{2} \rightarrow 900$

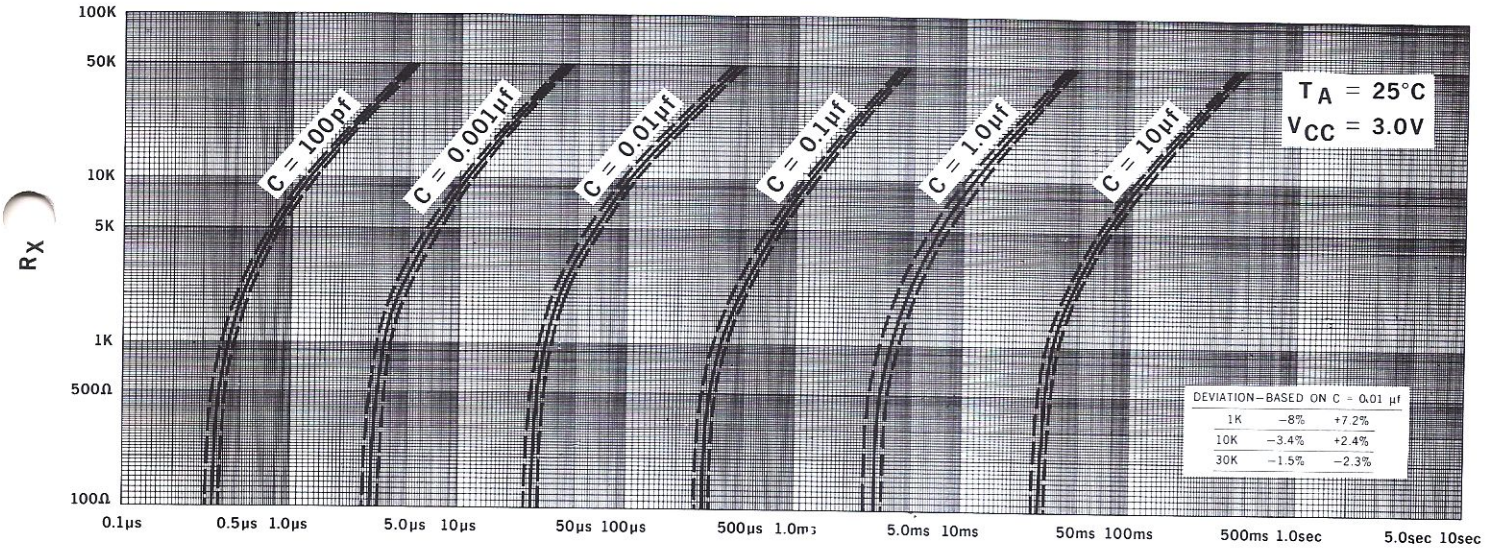

FIG. 16 PULSE WIDTH VERSUS EXTERNAL RESISTANCE (CONSTANT C) FOR $\frac{910}{2} \rightarrow 909$

ADDENDUM

The temperature-compensation circuit referred to below consists of two resistors in series. One resistor, labeled R_1, is of low temperature coefficient, and the other, labeled R_2 is any temperature-sensitive resistor whose resistance varies linearly with temperature. In the examples given below a resistor with a temperature coefficient of +0.7%/°C was selected.

1) Select average value of temperature coefficient from one of the four charts of circuit-performance temperature coefficient versus external resistance (Figs. 5 through 8).

2) Use the following equation to check the proper temperature coefficients:

$$T_1 = \frac{R_T}{R_1}\left[T_0 - \frac{R_2}{R_T}(T_2)\right] \qquad (1)$$

where T_0 = overall temperature coefficient of series pair
R_1 = resistance of fixed resistor
R_2 = resistance of temperature-sensitive resistor
T_1 = fixed-resistor temperature coefficient
T_2 = temperature-sensitive resistor temperature coefficient
R_T = total resistance of series pair at 25°C

Example:

1) Assume a required output pulse width of 2.7 msec using the chart of Fig. 15 for the $\frac{914}{2} \longrightarrow 900$ configuration

$$C = 1\ \mu F,\ R_X = 2.6\ K$$
$$R_T = R_X = 2.6\ K$$

2) Knowing R_X, find the average circuit-performance temperature coefficient from Fig. 7.

Since this is the temperature coefficient to be compensated, T_0's polarity should be opposite to that read from the graph of Fig. 7. In this case the multivibrator temperature coefficient = -0.075%/°C, and thus T_0 becomes +0.075%/°C.

3) Select R_2. If the total temperature coefficient (T_0) needed in the series pair is +0.075%/°C and if, as mentioned earlier, a temperature-sensitive resistor with a temperature coefficient of +0.7%/°C is selected, then T_0 is approximately 1/10th the value of T_2. To lower T_2 by a factor of 10, make R_2 equal $R_T/10$, since the temperature coefficient of the total series combination is approximately proportional to the ratio of the resistance values.

Therefore
$$R_2 = \frac{2.6\ K}{10} = 260\ \Omega$$

The closest standard value is 270 Ω.

4) R_1 then equals the difference between R_T and R_2, which in this case is 2.33 K.

$$R_1 = R_T - R_2 = 2.6\ K - 270 = 2.33\ K$$

The closest standard value is 2.4 K.

5) Calculate T_1 to check the approximation error of step #3 by using Eq. (1).

$$T_1 = \frac{R_T}{R_1}\left[T_0 - \frac{R_2}{R_T}(T_2)\right] = \frac{2.6\ K}{2.4\ K}\left[0.075 - \frac{0.270}{2.6}(0.7)\right]$$

$$= 1.08\ (0.075 - 0.073) = 1.08\ (0.002) = +0.0021/°C$$

$$= +21\ \text{ppm error}$$

The calculated error is within the temperature-coefficient range of a resistor of high stability.

ACKNOWLEDGEMENT

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